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(71) Applicant: **EndoArt S.A.**
1278 La Rippe (CH)

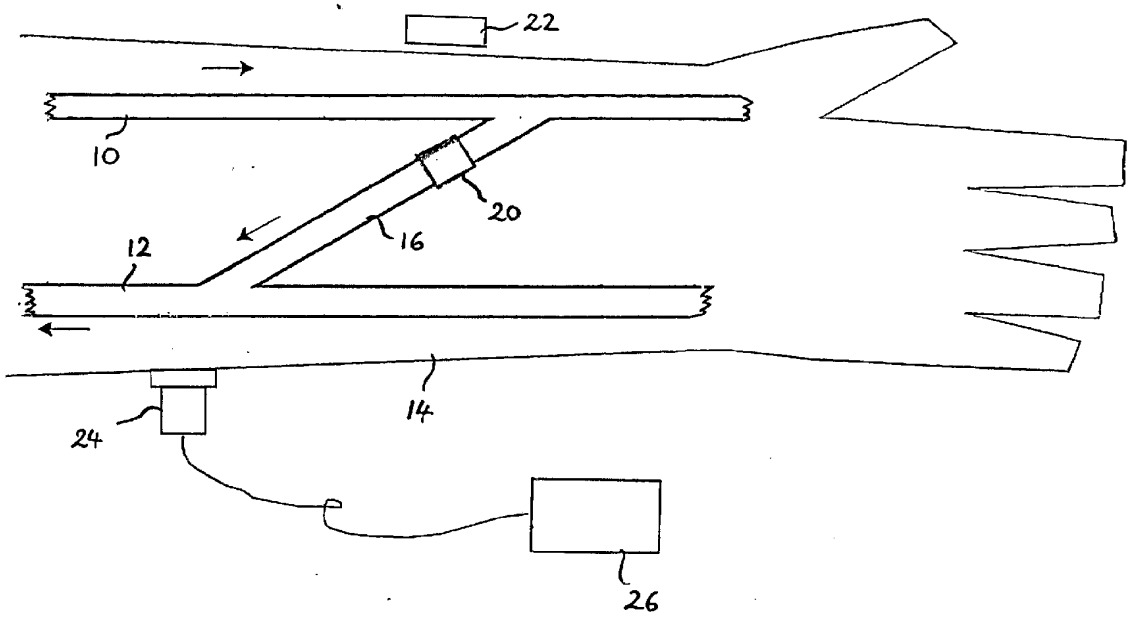
(72) Inventor: **Stergiopulos, Nikos c/o Endoart, S.A.**
1015 Lausanne (CH)

(74) Representative: **Price, Nigel John King**
J.A. KEMP & CO.
14 South Square
Gray's Inn
London WC1R 5LX (GB)

(54) Flow control device

(57) An arterio-venous graft 16 is provided with a constriction device 20 near its arterial end. The constriction device 20 is used to reduce the flow through the AV graft under normal conditions and to relieve the constriction when high flow through the AV graft is required, such as for vascular access for hemodialysis.

Fig. 3



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Description

[0001] This invention relates to a method of flow control, particularly for use in an arteriovenous graft, hereinafter referred to as an AV graft. The invention also relates to a device for controlling flow in an AV graft and a combination of such a device and an AV graft.

[0002] Patients with kidney disease, particularly those with end stage renal disease (ESRD), require hemodialysis in order to remove metabolites and the like from their blood stream. This can be a very time-consuming process, but the time can be lessened by providing a large blood flow to the hemodialysis machine. Even though this is done, hemodialysis can still take about four hours and is needed about three times a week.

[0003] In order to provide high blood flow to and from the hemodialysis machine, vascular access with high blood flow is needed. One method of providing this is illustrated in Figure 1. An artery 10 and a vein 12 are located in the arml4 of the patient. A vessel 16, known as an AV graft, is grafted to connect the artery 10 and vein 12. As the AV graft 16 is a direct connection between the artery 10 and vein 12 and has a relatively large cross-sectional area, a high flow through it occurs. The direction of flow is indicated by the arrows in Figure 1. Catheters (not shown) can be connected to the AV graft 16, when hemodialysis is required. The catheters can tap into the high flow through the AV graft 16 to provide a high flow to and from the hemodialysis machine.

[0004] However, there are also considerable problems with this technique. One of these, illustrated in Figure 2, is that stenosis occurs at the outflow tract where the AV graft 16 is connected to the vein 12, that is at the venous anastomosis side of the graft. The stenosis 18 is an unnatural narrowing of the vessel, and if unopened by angioplasty, the stenosis progresses until the vein is completely blocked. The stenosis is due to neo-intimal hyperplasia, that is the response of the vessel to the abnormal conditions. Various mechanisms are considered as possibly contributing to the stenosis development. The flow through the vein is typically 10 to 20 times higher than normal. This leads to turbulence and flow separation such that the flow is not smooth or laminar, and the stenosis develops as a result. Another factor is that the vein is exposed to a higher blood pressure than normal, because it is directly connected to the artery. The blood pressure in an artery is typically 100 mm Hg, whereas the blood pressure in a vein is typically 5 mm Hg. The vein tends to arterialise in response to this, for example by thickening of the vein wall and this may contribute to the stenosis. A further possible factor is that, in the presence of the graft, the flow in the vein is pulsatile. There is a significant compliance mismatch between the AV graft, which, if synthetic, is quasi-rigid, and the vein which is compliant. The pulsatile flow produces an oscillating stress concentration at the junction, i.e. suture line, between the AV graft 16 and the vein 12. Although the suture usually does not fail, the stenosis may be in response to the oscillating stress concentrated at the junction.

[0005] This is a considerable problem. In 90% of AV grafts, stenosis develops at the venous anastomosis side. AV graft survival is around only 1.5 years. Conventionally, alleviation of this problem requires surgery, such as angioplasty to remove the stenosis or surgery to implant a new AV graft in a different limb of the patient.

[0006] A further problem is that the AV graft 16 effectively provides a short circuit between the artery 10 and vein 12 and the high flow through the AV graft 16 requires a huge additional cardiac output. Normal cardiac output is typically 5 litres per minute, but with the AV graft in place this can increase to 7 litres per minute. This large additional cardiac output can be very problematic indeed, and can result in fatal cardiac failure for about 5% of AV graft patients.

[0007] According to the present invention there is provided a method of flow control in a AV graft or AV fistula used for vascular access for an extracorporeal circuit, said method comprising the steps of:

(a) applying partial constriction to a vessel to provide a reduced flow through said AV graft or AV fistula, when flow through said extracorporeal circuit is not occurring; and;

(b) changing the degree of constriction, to modify the flow through the AV graft or AV fistula, when flow through said extracorporeal circuit is to occur.

[0008] Applying partial constriction can reduce or eliminate turbulence, and lower the blood pressure in the vein. The constriction can also act as a strong wave reflector to reduce or eliminate the pulsatile flow at the venous anastomosis. All of these can alleviate stenosis, prolong the life of the AV graft or AV fistula and reduce the necessary cardiac output. Changing the degree of constriction when flow through said extracorporeal circuit is to occur enables a high flow to be provided for vascular access.

[0009] The constriction of the vessel is only partial, preferably to maintain a reduced but significant residual flow through the AV graft to avoid thrombosis, and to keep the vein matured and able to handle the high flow when necessary.

[0010] Preferably the constriction is applied over an elongate portion of the vessel. This enables the flow control to be achieved by viscous dissipation in favour of turbulent dissipation.

[0011] Preferably the constriction is applied at a plurality of positions along the vessel and/or the profile of the constriction is controlled along its length. This enables turbulence caused by the constriction to be minimised.

[0012] Preferably the constriction reduces the cross-sectional area of the lumen of the vessel, but maintains the length of the perimeter thereof, again to favour viscous dissipation.

[0013] Preferably, when applying the constriction to the vessel, the flow at the venous anastomosis of the AV graft or AV fistula is monitored so that when constricted, the flow is maintained at a level below the onset of turbulence.

[0014] Preferably the vessel is an AV graft.

[0015] Preferably the constricting step comprises constricting said AV graft at its arterial end. This enables any turbulence caused by the constriction to subside before the blood flow reaches the venous anastomosis.

[0016] The invention provides a device for controlling flow in an AV graft or AV fistula used for vascular access for an extracorporeal circuit, said device comprising:

a) means for applying partial constriction to a vessel, to provide a reduced flow through said AV graft or Av fistula, when flow through said extracorporeal circuit is to occur; and
b) means for changing the degree of constriction, to modify the flow through the AV graft or AV fistula, when flow through said extracorporeal circuit is to occur.

[0017] The invention also provides a device, for controlling flow in an AV graft, said device comprising an actuator for releasably constricting said AV graft; and a rotatable member for driving said actuator.

[0018] Preferably the rotatable member comprises a drive shaft of a motor or comprises a rotor rotatable by an externally applied magnetic field.

[0019] Preferably the motor is an electrical micromotor.

[0020] The invention also provides a device, for controlling flow in an AV graft, said device comprising a deformable member which is reversibly deformable by a change in temperature or magnetic field; and an actuator acted on by said deformable member for releasably constricting said AV graft, wherein said deformable member is deformable between a first state in which said actuator applies constriction to said AV graft, and a second state in which said actuator reduces said constriction of said AV graft.

[0021] Preferably the thermally deformable member comprises a shape-memory material or a liquid filled capsule.

[0022] Preferably the device of the invention further comprises an antenna for receiving signals for controlling the actuator. This avoids the need for access to the device through the skin and the potential risk of infection.

[0023] Preferably the device further comprises a converter for converting radio frequency energy received by the antenna into energy for powering the device to operate the actuator. This has the advantage of avoiding the need for an internal power source, such as a battery, in the device, and radio frequency activated devices are NMR-proof.

[0024] The invention further provides a device, for controlling flow in an AV graft, said device comprising an actuator for releasably constricting said AV graft, wherein said actuator comprises a clip having two constriction portions with an adjustable separation therebetween for accommodating said AV graft and a control portion for releasably holding said two constriction portions such that said separation is held at at least one predetermined amount.

[0025] Preferably the constriction portions are integrally formed as one member which makes the device simple and cheap to fabricate.

[0026] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic view of a human lower arm, illustrating a conventional AV graft in situ;

Fig. 2 is a close-up view of the venous anastomosis of Fig. 1, illustrating a problem associated with the AV graft of Figure 1;

Fig. 3 is a schematic view of a human lower arm, illustrating an arrangement according to the present invention;

Figs. 4(a) and 4(b) are schematic cross-sectional views of a first embodiment of apparatus according to the present invention, shown applied to an AV graft;

Fig. 4(c) is a plan view of a deflectable membrane of an embodiment of the invention;

Fig. 5 shows a second embodiment of an apparatus according to the present invention;

Figs. 6(a) and 6(b) show a third embodiment of an apparatus according to the invention in cross-section and plan view, respectively;

Figs. 7 and 8 show cross-sectional views of fourth and fifth embodiments of apparatus according to the invention; and

Figs. 9, 10 and 11 are explanatory diagrams for illustrating further aspects of the present invention.

[0027] Fig. 3 shows an arrangement according to the present invention, with corresponding parts labelled the same as in Fig. 1. The AV graft 16 may be an artificial vessel, for example, made of PTFE or GORE-TEX™ or other synthetic material, or the AV graft may be an autologous graft. As illustrated in Fig. 3, the AV graft 16 is connected to an artery 10 and vein 12 in the arm 14 of the patient. However, the AV graft 16 may, of course, be located in other parts of the body, for example the leg, groin or neck. A device 20 is provided for controlling

blood flow in the AV graft 16. During the normal activities of the patient, the device 20 is used to constrict the AV graft 16 such that there is a reduced or residual flow therethrough. When flow through an extracorporeal circuit, such as a hemodialysis machine, is required, the degree of constriction is reduced, partially or fully, so that there is an increased, high flow through the AV graft 16. Catheters (not shown) can tap into the high flow in the AV graft 16 to provide high flow to and from a hemodialysis machine. The catheters may be upstream or downstream of the device 20 or may be provided on opposite sides of the device 20. A single catheter with a double lumen may also be used for flow to and from the AV graft 16.

[0028] As illustrated in Fig. 3, the constriction device 20 is used to constrict the AV graft 16 at its upstream end, in the vicinity of its connection with the artery 10. Preferably the constriction device 20 is wholly implanted within the patient and an external controller 22 is used telemetrically to control the constriction device 20.

[0029] When high flow through the AV graft 16 is no longer required, the constriction device 20 is used to reapply constriction to reduce blood flow. A turbulence measuring device 24, 26 may be used to monitor turbulence in the vicinity of the venous anastomosis while the flow through the AV graft 16 is being reduced. As the degree of constriction is increased, the flow rate reduces such that a level will be reached at which turbulent flow substantially ceases to be detected by the turbulence measuring device. When this occurs, further change in constriction can be stopped and the flow maintained at that level below the onset of turbulence. Alternatively, the constriction may be increased until the turbulence has been diminished to a predetermined level, but not totally abolished. Preferably this dimished turbulence intensity is below the level at which stenosis may occur, but the flow rate is still sufficient to keep the vein matured. In this way an optimal quiescent flow can be established in the vicinity of the venous anastomosis side of the AV graft.

[0030] The turbulence measuring device 24, 26 can be a conventional Doppler device or a phonoangiographer and may advantageously be connected to the controller 22 or constriction device 20 automatically to control adjustment of the flow rate, or this may be done manually.

[0031] Further features of the method of the present invention will be apparent from the following description of devices according to the invention.

[0032] Figs. 4(a) and 4(b) are longitudinal and transverse cross-sections, respectively, of a constriction device 20 and control device 22. The control device 22 has an antenna 30 for transmitting signals to an antenna 32 provided on the constriction device 20. The antennae 30, 32 are electromagnetically coupled to each other, but are of course on opposite sides of the skin (not shown) of the patient. A receiver 34 connected to antenna 32 sends electrical power to a motor 36 in response to the transmitted signal.

[0033] The constriction device 20 may contain an internal power source, such as a battery, which is controlled by the receiver 34 to deliver electrical power to the motor 36. Alternatively, the receiver 34 may comprise a radio frequency to DC converter and modulator, in which case radio frequency signals emitted by the antenna 30 are picked up by the antenna 32 and these signals are converted by the receiver 34 into electrical power to drive the motor 36, rather than the signals being used to control an internal power source of the device, thereby eliminating the need for batteries in the device which would need to be replaced periodically.

[0034] The motor 36 is a miniature motor, also known as a micro-machine, and when provided with electrical power it can be used to rotate a drive shaft 38 in either direction, or in one direction only, provided that the actuator performs a periodic displacement even if the micromotor shaft 38 always turns in the same direction. The dimensions of the micromotor 36 are sufficiently small to enable it to be encapsulated in an implantable enclosure, for example the motor may be 2 mm thick and 15 mm long. A rotary to linear transmission 40 converts the rotation of the drive shaft 38 into linear motion of an actuator comprising members 42, 44 and 46.

[0035] Members 42 and 44 are rods or bars and member 46 is, for example, a fine titanium membrane that is in contact with the AV graft 16 or presses upon the AV graft through an intermediate material.

[0036] As shown in Figs. 4(a) and 4(b), the actuator 42, 44, 46 is constricting the AV graft 16, such that the cross-sectional area of its lumen 48 is reduced. By sending appropriate signals, and through action of the motor 36, the constriction can be relieved by motion of the actuator, when high flow is required, and the position of the membrane 46 in this high flow state is indicated by the dashed line 50.

[0037] The constriction device 20 is encapsulated in an enclosure 52, such as a titanium or ceramic box, through which the AV graft can pass. The antenna 32 is located outside the enclosure 52 so that it is not screened by the enclosure.

[0038] The device may optionally include a sensor, not shown, such as a sensor for measuring the position of the actuator or for counting the number of revolutions of the drive shaft 38. Sensors for measuring flow, turbulence or pressure may also be included. Information from the sensor(s) can then be transmitted from the constriction device 20 to the control device 22 via the antennae 30, 32, so that the controller 22 can control the constriction more precisely.

[0039] Fig. 5 illustrates an alternative constriction device 20 in the form of a clip. The actuator of the device comprises a pair of constriction portions 60, 62 separated by a gap through which the AV graft 16 passes. The separation between the constriction portions 60, 62 can be reduced by applying pressure to the skin 64 of the patient to constrict the AV graft 16. A control portion 66

comprises a series of grooves or notches engageable by an insertion portion 68 of the constriction portion 60. Pressure applied to the skin 64 moves the insertion portion 68 from the position shown in Fig. 5 into successively lower notches. When the required level of constriction is achieved, the engagement of the insertion portion 68 in the particular notch of the control portion 66 maintains that level of constriction.

[0040] A pressing device 70 may be used for this process and may comprise a sensor that detects the motion of the insertion portion 68 from one notch to the next so that the position of the constriction portions is known and an optimal level of constriction applied.

[0041] When high flow through the AV graft 16 is required, the constriction can be reduced by again applying pressure to the skin of the patient, but this time by pressing on a release portion 72. This splays the control portion 66 so that the insertion 68 disengages from the notches and the opening between the constriction portions 60, 62 increases.

[0042] As shown in Fig. 5, the constriction device 20 is formed from a single piece, such as by moulding it from a biologically compatible plastics material. This makes it very simple and cheap to fabricate.

[0043] Another embodiment of the constriction device is shown in Figs. 6(a) and 6(b). It comprises an actuator plate 80, within an enclosure 82, for squeezing on the AV graft 16. A rotor 84 is screwed onto a threaded shaft 86. The rotor 84 comprises a series of magnetic north and south poles alternating around the shaft 86. The rotor 84 can comprise any suitable magnetic material, such as ferrite.

[0044] Application of an alternating or rotating magnetic field from outside the patient can cause the rotor 84 to revolve about the axis of the shaft 86. The threaded engagement between the rotor 84 and shaft 86 causes the rotor 84 to translate in the axial direction of the shaft 86, the direction of translation depending on the sense of rotation of rotor. In this way the externally magnetic field can be used to move the rotor 84 along the shaft 86 to urge the actuator plate 80 against the AV graft 16 to apply constriction thereto, or to release pressure from the actuator plate 80 and reduce the constriction when high flow through the AV graft 16 is required.

[0045] Figs. 7 and 8 show two further embodiments of the constriction device 20 of the invention which both operate thermally. Each device has an actuator comprising a movable member 90 and a flexible membrane 92 for constricting an AV graft 16, the device being housed in an enclosure 94.

[0046] In the embodiment of Fig. 7, the actuator member 90 is connected to a sheet 96 made of a heat-deformable material. This is shown in its normal state at body temperature whereby the AV graft 16 is constricted to reduce the quiescent flow therethrough. On raising the temperature of the sheet 96 it deforms into the shape indicated by the dashed line 98 thereby pulling on the actuator 90, 92 to reduce the constriction on the AV graft 16. The material of the sheet 96 may be a shape-memory material, such as a so-called smart metal, or it could be a bi-metallic strip or any other suitable material that deflects on changing temperature, or a shape memory material that is magnetically activated.

[0047] In the device of Fig. 8, the actuator member 90 is connected to a deformable membrane 100 which defines one surface of a liquid filled capsule 102 containing a liquid with a low boiling point, such as just above body temperature, for example around 39°C. Under normal conditions the capsule 102 contains liquid and the actuator 90, 92 squeezes the AV graph 16 to reduce blood flow. On increasing the temperature of the substance in the capsule 102 above its boiling point, at least some of the liquid vaporises which results in an overall increase in volume of the contents of the capsule 102. This expansion deflects the membrane 100 and a force is transmitted via the member 90 to lift the flexible membrane 92 to relieve the constriction of the AV graph 16. The position of the deformable membrane 100 when in this state is indicated by the dashed line 104.

[0048] The devices 20 shown in Figs. 7 and 8 may be provided with an optional heater 106, such as an electrical resistance. When it is desired to increase the blood flow through the AV graft 16, electric current is passed through the heater 106 to raise the temperature of the sheet 96 or liquid filled capsule 102 to move the actuator as described above. The electrical current may be provided by a battery associated with the device and controlled by signals from an external controller as described with reference to Figs. 4(a) and 4(b), or the electrical current may be provided by a radio frequency converter which converts radio frequency radiation into electrical power, without the need for an internal battery, as also described with reference to Fig. 4(a) and 4(b). Alternatively, the increase in temperature necessary to change the state of the thermal device may be provided by an external heat source. This eliminates the need for the heater 106. The external heat source may take the form of, for example, an infrared lamp directed onto the skin in the vicinity of the device 20. The heater 106 could also be an antenna which heats up when an appropriate electromagnetic field is applied.

[0049] When high flow through the AV graft 16 is no longer required, such as when hemodialysis has been completed, power to the heater 106 is cut off, or the external heat source removed. The sheet 96 or fluid filled capsule 102 cools back to normal body temperature and returns to the configurations shown in Figs. 7 and 8 in which the actuator 90, 92 is squeezing the AV graft 16.

[0050] All of the above described constriction devices are intended to be wholly implantable within the patient. The enclosures 52, 82, 94 comprise a titanium box and the dimensions of the sides in transverse cross-section may be in the region of 10 to 30 mm, the unconstricted diameter of an AV graft being typically 5 to 8 mm. The flexible membrane 46, 92, in contact with the AV graft 16 may be a very thin (i.e. 20 to 60 μm thick) titanium

sheet or a thicker titanium membrane preferably with appropriate corrugations 47 to facilitate deflection, as shown in plan view in Fig. 4(c). The corrugations can be seen in cross-section in Figs. 4(a), 4(b), 7 and 8. The region surrounding the AV graft 16, but within the respective enclosure, such as the region 110 shown in Figs. 7 and 8 may contain a deformable, but incompressible, material such as gel to control the constriction of the AV graft 16.

[0051] Fig. 9 shows schematically a constriction, such as in an AV graft 16. The normal diameter of the vessel is D, the constricted diameter is d, and the constriction is applied over a length L. It is preferred that the method and devices of the present invention apply the constriction over an elongate portion of the AV graft 16, for example as shown in Fig. 4(a). Preferably the length L is at least twice the original diameter D, and L may even be five to ten or more times the diameter D. The reasons for this are as follows. For a given flow rate Q through the AV graft 16, the viscous losses are proportional to LQ, whereas the turbulent losses are proportional to $[(D/d)^2-1]^2Q^2$. These two losses contribute to the overall dissipation caused by the constriction which results in the pressure drop and reduced flow rate. An acute localised constriction produces much turbulence which can cause thrombosis or unwanted stenosis downstream at the venous anastomosis, or in the AV graft itself if it is made of living tissue. The same overall flow reduction can be achieved by increasing the length of the constriction to increase viscous loss, but reducing turbulent loss.

[0052] One way to increase the length of the constriction is to provide multiple constriction devices in series along the AV graft 16. Another method is to provide a single elongate actuator within the device or multiple actuators disposed along the length of the device.

[0053] Fig. 10 illustrates a further technique for reducing turbulence caused by the constriction, namely by controlling the profile of the constriction such that abrupt transitions in diameter are avoided. The profile of the constriction can be controlled by providing a plurality of actuators 120, each of which squeezes the AV graft 16 by a controlled amount. The actuators 120 may all be provided within a single constriction device, or each actuator 120 may be provided in a respective constriction device disposed in series along the AV graft 16. Alternatively, a single actuator of a predetermined profile may be used to cause a desired constriction profile.

[0054] A further technique for favouring viscous dissipation over turbulent dissipation is illustrated with reference to Fig. 11. A transverse cross-section of the unconstricted AV graft is approximately circular as shown in the centre of Fig. 11. Applying an isotopic force around the periphery to squeeze the vessel approximately equally in all directions would tend to reduce the cross-section of the vessel to be a circle of smaller diameter. However, viscous losses are related to the area of the wall of the vessel and hence to the perimeter of the cross-section. By squeezing the AV graft 16 unequally in different directions, the perimeter of the lumen can be maintained substantially constant in length while reducing its cross-sectional area. Various exemplary resulting shapes are shown in Fig. 11. The arrows illustrate the directions and points of application of the squeezing force. The devices according to the invention can achieve constrictions of these shapes by a variety of ways, such as having ridged actuators, or a plurality of actuators applying pressure in different directions or surrounding the AV graft 16 by a gel to control the shape of the deformation.

[0055] A further feature of the invention is to adhere the outer surface of the AV graft to the actuator using a glue. According to Bernoulli's equation, $p + \frac{1}{2}\rho v^2$ is constant, where p is pressure, p is viscosity and v is flow velocity. At a constriction, the flow velocity increases to maintain throughput. At sufficiently high velocity, the pressure given by Bernoulli's equation can become lower than the external pressure on the vessel or even become negative. Thus, at a constriction it is possible for collapse of the vessel to occur because the reduced pressure sucks the walls inwards. The flow of course then stops and the vessel recovers, but vessel collapse is problematic and results in erratic flow conditions. Gluing the wall of the AV graft to the actuator prevents collapse by maintaining a minimum diameter of the AV graft, even when constricted. AV graft collapse may also be prevented if the constriction is appropriately shaped, as shown in some of the examples in Fig. 11, to resist further buckling under reduced pressure.

[0056] As previously mentioned, in one arrangement catheters for extracorporeal flow to and from the AV graft 16 may be provided on opposite sides of the device 20. In this case it can be beneficial to increase constriction of the graft during e.g. hemodialysis in order to augment flow through the extracorporeal machine. For the rest of the time, the constriction is still partially applied to alleviate the problems, such as caused by turbulence, whilst keeping the vein matured.

[0057] The method and device of the invention can also be used with AV fistulas, in which case the flow control device is placed on the artery or vein, just proximal or distal to the fistula, respectively.

Claims

1. A device for controlling flow in an AV graft or AV fistula used for vascular access for an extracorporeal circuit, said device comprising:

   a) means for applying partial constriction to a vessel, to provide a reduced flow through said AV graft or AV fistula, when flow through said extracorporeal circuit is to occur; and
   b) means for changing the degree of constriction, to modify the flow through the AV graft or AV fistula, when flow through said extracorpor-

eal circuit is to occur.

2. A device according to claim 1, wherein said vessel is said AV graft.

3. A device, for controlling flow in an AV graft, said device comprising:

an actuator for releasably constricting said AV graft; and
a rotatable member for driving said actuator.

4. A device according to claim 3, further comprising a motor, said rotatable member being a drive shaft of said motor.

5. A device according to claim 4, wherein said motor is an electrical micromotor.

6. A device according to claim 4, wherein said rotatable member comprises a rotor having a plurality of magnetic poles, such that rotation of said rotor can be induced by an externally applied varying magnetic field.

7. A device according to claim 6, wherein said rotor is threadedly engaged with a shaft such that rotation of said rotor causes translational motion between said rotor and shaft.

8. A device, for controlling flow in an AV graft, said device comprising:

a deformable member which is reversibly deformable by a change in temperature or magnetic field; and
an actuator acted on by said deformable member for releasably constricting said AV graft,
wherein said deformable member is deformable between a first state in which said actuator applies constriction to said AV graft, and a second state in which said actuator reduces said constriction of said AV graft.

9. A device, according to claim 8, wherein said deformable member comprises a shape-memory material.

10. A device, according to claim 8, wherein said deformable member comprises a capsule containing a substance, wherein said substance is substantially in a liquid phase when said member is in said first state, and said substance is at least partially vaporizable to deform said member to said second state.

11. A device according to any one of claims 8 to 10, further comprising an internal heater.

12. A device according to any one of claims 8 to 10, wherein said member is deformable by an externally applied heat source.

13. A device according to claim 12, wherein said heat source comprises an infrared lamp.

14. A device according to any one of claims 3 to 13, further comprising an antenna for receiving signals for controlling said actuator.

15. A device according to claim 14, further comprising a converter for converting radio frequency energy received by said antenna into energy for powering the device to operate said actuator.

16. A device according to claim 14 or 15, further comprising a sensor for sensing the state of said actuator and transmitting a signal via said antenna indicative of said state.

17. A device according to claim 14, 15 or 16, further comprising one or more sensors for sensing at least one of pressure, flow rate and turbulence and transmitting a corresponding signal via said antenna.

18. A device according to any one of claims 3 to 17, further comprising a battery.

19. A device according to any one of claims 3 to 18, wherein said actuator further comprises a flexible membrane for pressing on said AV graft.

20. A device according to claim 19, wherein said membrane comprises at least one currugation.

21. A device, for controlling flow in an AV graft, said device comprising:

an actuator for releasably constricting said AV graft,
wherein said actuator comprises a clip having two constriction portions with an adjustable separation therebetween for accommodating said AV graft and a control portion for releasably holding said two constriction portions such that said separation is held at at least one predetermined amount.

22. A device according to claim 21, wherein at least one of said constriction portions comprises an arm moveably joined to said other constricting portion.

23. A device according to claim 21 or 22, wherein said constriction portions are resiliently hinged to each other.

24. A device according to claim 21, 22 or 23, wherein

said constriction portions are integrally formed as one member.

25. A device according to any one of claims 21 to 24, wherein said control portion comprises at least one notch engageable by an insertion portion provided on respective ones of said constriction portions.

26. A device according to claim 25, wherein pressure on one said constriction portion is effective to reduce said separation and to engage said insertion portion in a said notch to maintain said reduced separation.

27. A device according to claim 25 or 26, further comprising at least one release portion, wherein pressure on said release portion is effective to disengage said insertion portion from said notch to allow said separation to increase.

28. A device according to any one of claims 3 to 27, wherein said actuator is arranged to constrict said AV graft non-uniformly around its transverse cross-sectional periphery.

29. A device according to any one of claims 3 to 28, wherein said actuator is shaped to define a predetermined profile for said constriction.

30. A device according to any one of claims 3 to 29, further comprising a plurality of said actuators.

31. A device according to any one of claims 3 to 30, adapted to constrict said AV graft along an elongate portion thereof.

32. A device according to any one of claims 3 to 31, wholly implantable within a patient.

33. A device according to claim 32, further comprising a titanium or ceramic implantable enclosure.

34. A combination of a device according to any one of claims 2 to 33 and an AV graft.

35. A combination according to claim 34, wherein said actuator is adhered to said AV graft to prevent uncontrolled constriction of said AV graft.

36. A combination according to claim 35, wherein said constriction is shaped to resist further buckling under reduced pressure.

37. A combination according to claim 34, 35 or 36, wherein said actuator is positioned at the upstream end of said graft.

38. A combination according to any one of claims 34 to 37, further comprising a deformable, but substantially incompressible, medium at least partially surrounding said AV graft at the location of said actuator.

39. A combination according to any one of claims 34 to 38, comprising a plurality of said devices disposed along said graft.

40. A combination according to any one of claims 34 to 39, wherein one end of said AV graft is connected to an artery and the other end of said AV graft is connected to a vein.

41. A device according to any one of claims 1 to 33 or a combination according to any one of claims 34 to 40, further comprising a measuring device coupled thereto, to control the level of constriction applied by said actuator.

42. A device according to claim 41, wherein said measuring device is for measuring at least one of flow rate, turbulence and pressure.

43. A device or combination according to claim 42, wherein said measuring device comprises a Doppler device or a phonoangiographer.

44. A method of facilitating blood flow towards a blood extraction point associated with an AV graft or AV fistula, said method comprising the steps of:

(b) operating a constriction device to change the degree of constriction of a partially constricted vessel when increased blood flow to said blood extraction point is desired; and
(a) operating said constriction device to return said vessel to its original partially constricted state when increased blood flow to the blood extraction point is not desired.

45. A method of flow control in an AV graft or AV fistula used for vascular access for an extracorporeal circuit, said method comprising the steps of:

(a) applying partial constriction to a vessel to provide a reduced flow through said AV graft or AV fistula, when flow through said extracorporeal circuit is not occurring; and
(b) changing the degree of constriction, to modify the flow through the AV graft or AV fistula, when flow through said extracorporeal circuit is to occur.

46. A method according to claim 44 or 45, wherein step (b) comprises decreasing the degree of constriction of said vessel.

47. A method according to claim 44 or 45, wherein step (b) comprises increasing the degree of constriction of said vessel.

48. A method, according to claim 44, 45, 46 or 47, wherein said step (a) comprises applying constriction over an elongate portion of said vessel.

49. A method, according to any one of claims 44 to 48, wherein said step (a) comprises constricting said vessel at a plurality of positions along it.

50. A method, according to any one of claims 44 to 49, wherein said step (a) comprises controlling the profile of the constriction along its length.

51. A method according to any one of claims 44 to 50, wherein said step (a) comprises controlling the profile of the constriction around the transverse cross-sectional periphery of said vessel.

52. A method according to any one of claims 44 to 51, wherein said step (a) comprises squeezing said vessel by applying force at one or more points around said periphery in a non-uniform manner.

53. A method according to any one of claims 44 to 52, comprising maintaining substantially constant the length of the perimeter of said vessel in transverse cross-section between steps (a) and (b).

54. A method according to any one of claims 44 to 53, wherein step (a) further comprises monitoring the flow at the venous end of said AV graft or AV fistula;

increasing the constriction until the monitored flow substantially ceases to be turbulent or has a reduced turbulence intensity; and
maintaining the constriction so that the flow is kept non-turbulent or with a reduced turbulence intensity.

55. A method according to any one of claims 44 to 54, wherein step (a) comprises maintaining constriction at a level such that the flow rate is below the flow rate at which onset of turbulence occurs.

56. A method according to any one of claims 44 to 55, wherein said vessel is an AV graft.

57. A method according to claim 56, wherein step (a) comprises constricting said AV graft at its arterial end.

58. A method according to any one of claims 44 to 57, wherein said extracorporeal circuit comprises a hemodialyser.

59. A method of flow control in an AV graft, comprising the step of constricting said AV graft at its arterial end.

60. A method of flow control in an AV graft, comprising the step of applying constriction over an elongate portion of said AV graft.

61. A method of flow control in an AV graft, comprising the step of constricting the AV graft at a plurality of positions along said AV graft.

62. A method of flow control in an AV graft comprising the step of constricting said AV graft so as to reduce the cross-sectional area of the lumen of said AV graft at said constriction while substantially maintaining the length of the perimeter of said AV graft.

63. A device or combination substantially as described herein with reference to the accompanying drawings.

64. A method substantially as described herein with reference to the accompanying drawings.

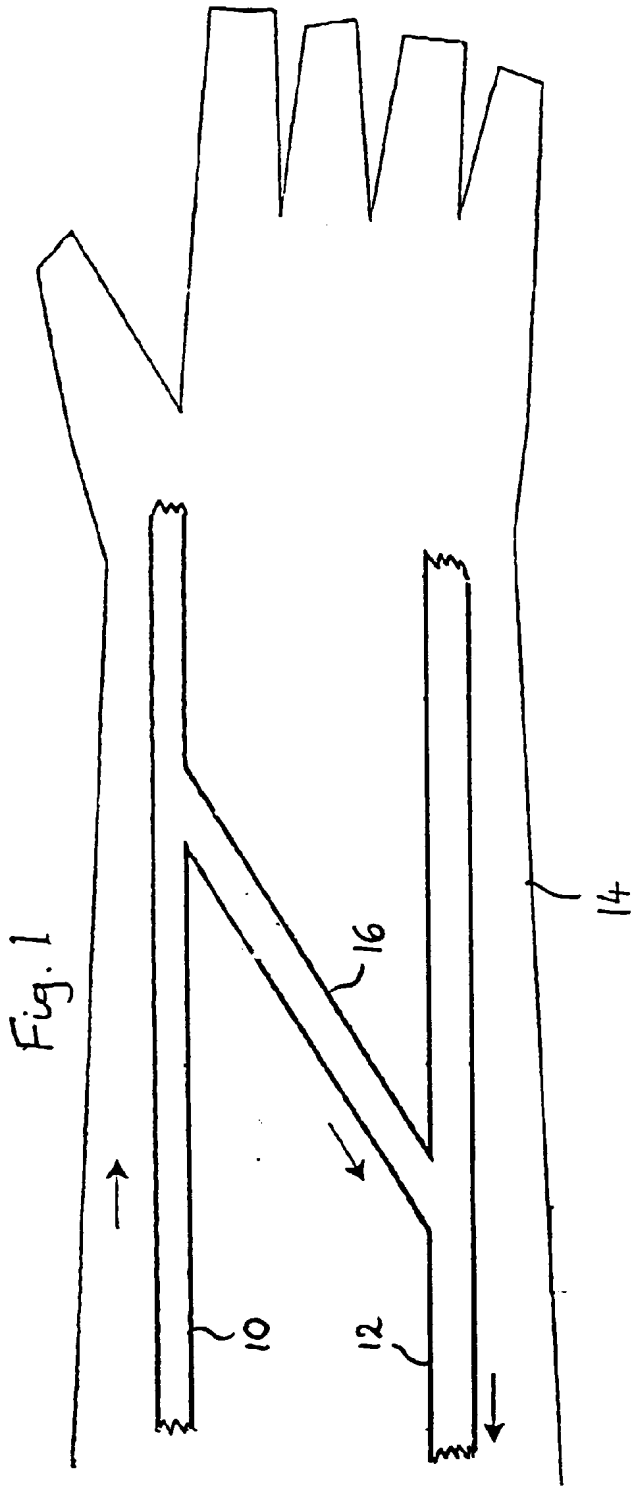


Fig. 1

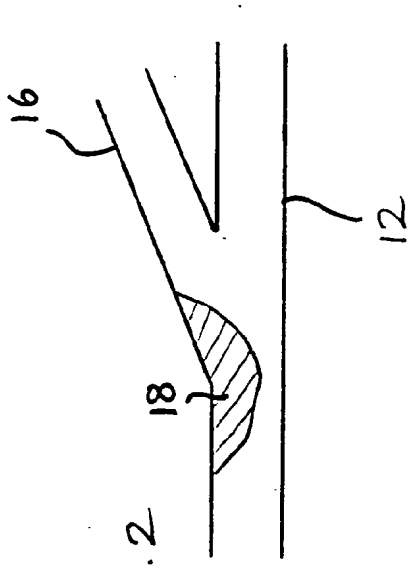


Fig. 2

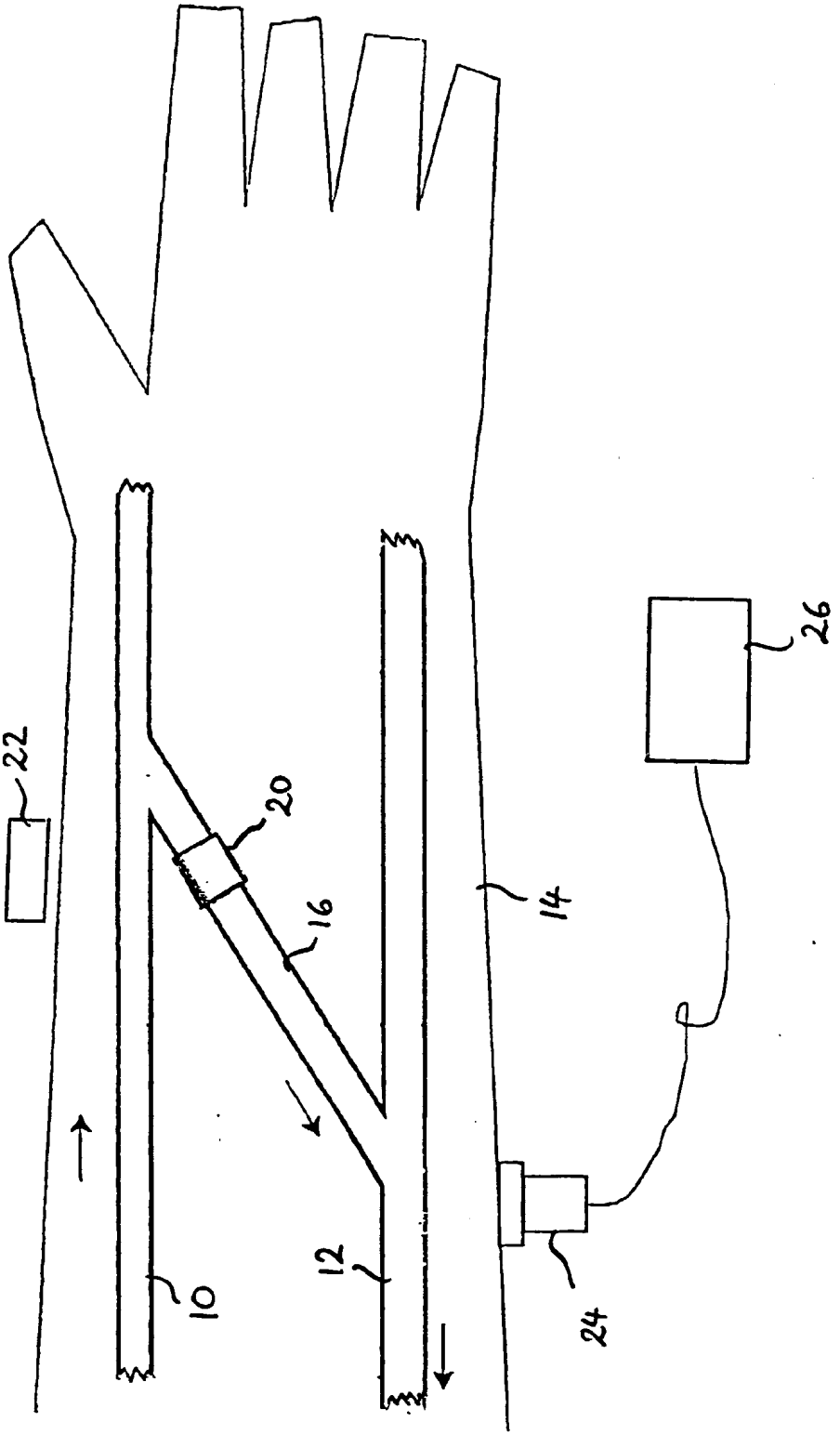


Fig. 3

Fig. 4(a)

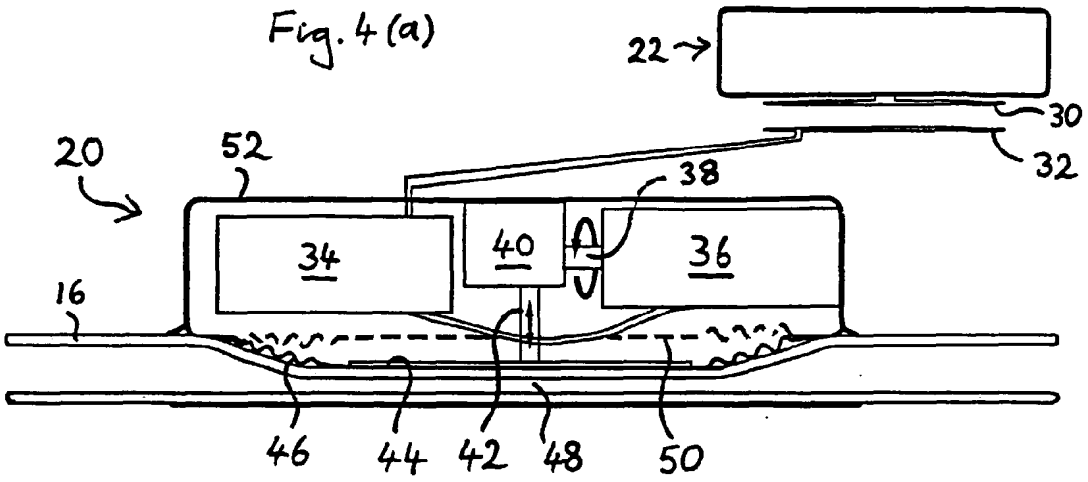


Fig. 4(b)

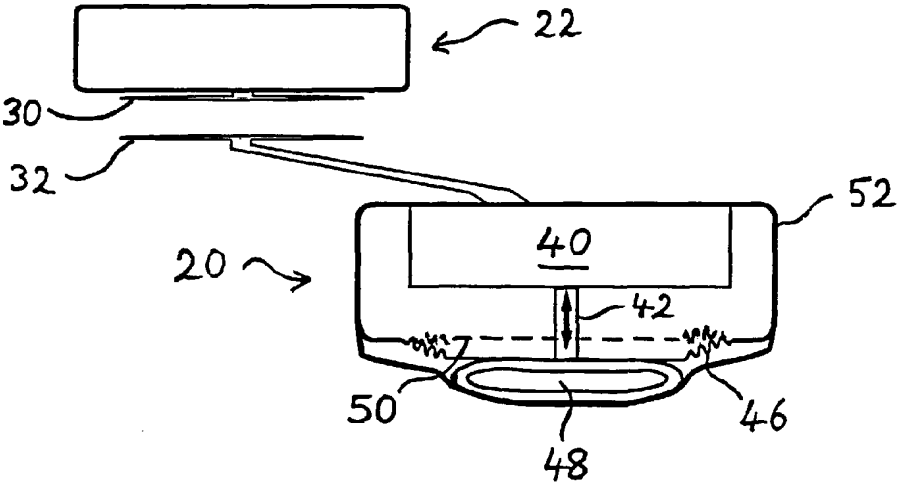
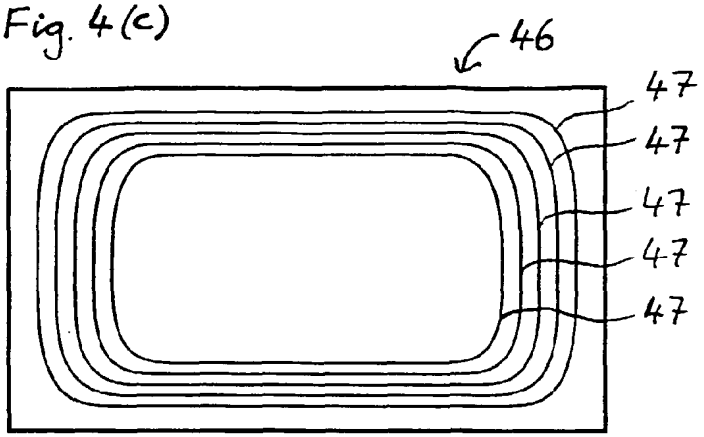


Fig. 4(c)



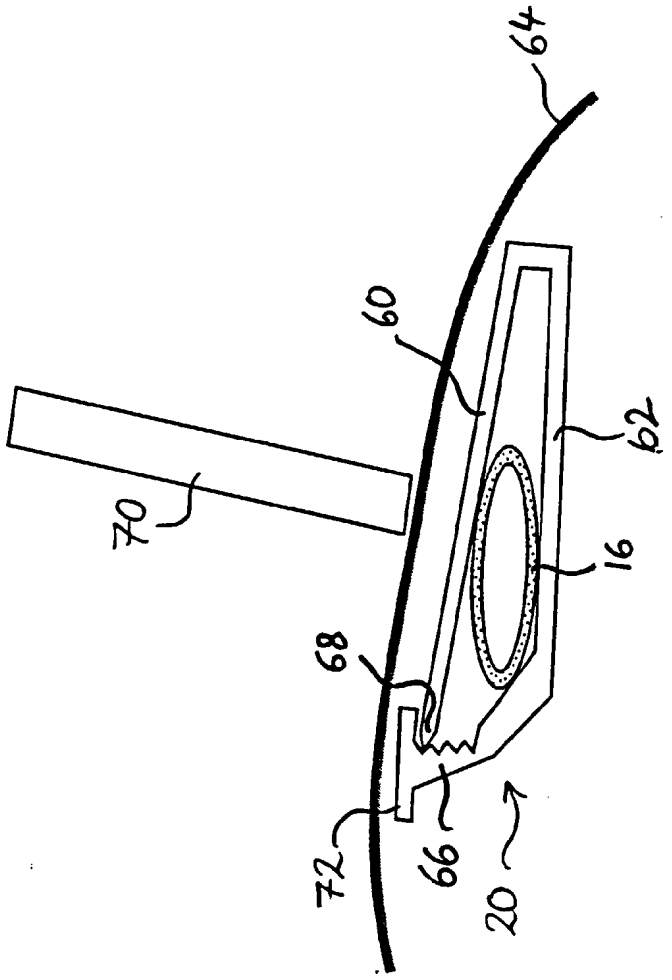


Fig. 5

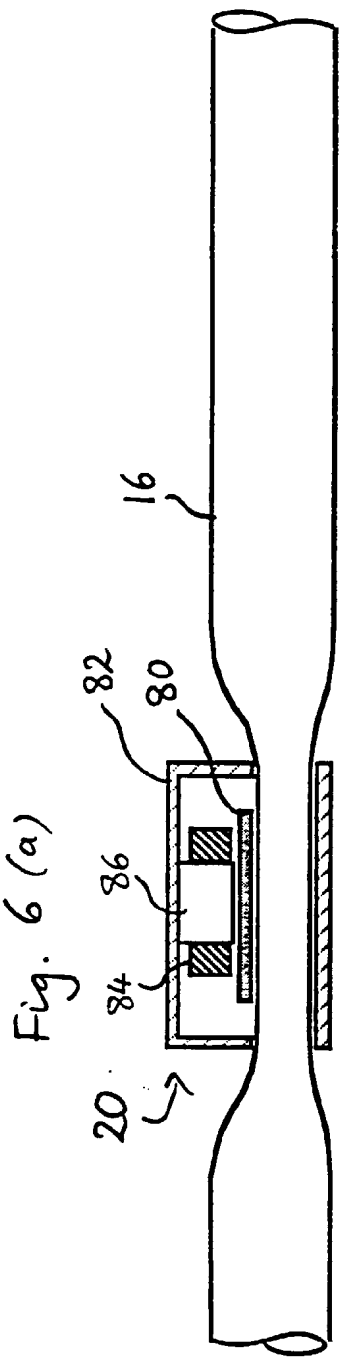


Fig. 6 (a)

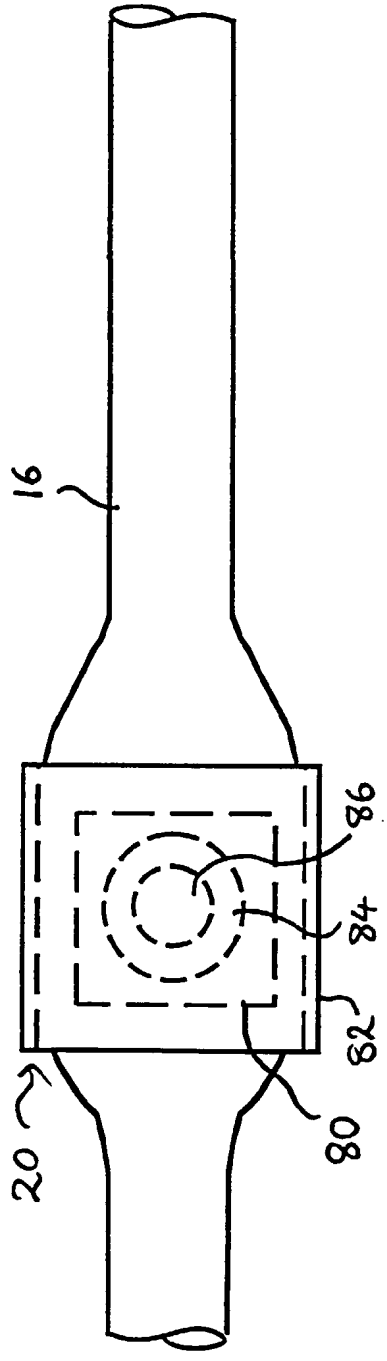


Fig. 6 (b)

Fig. 7

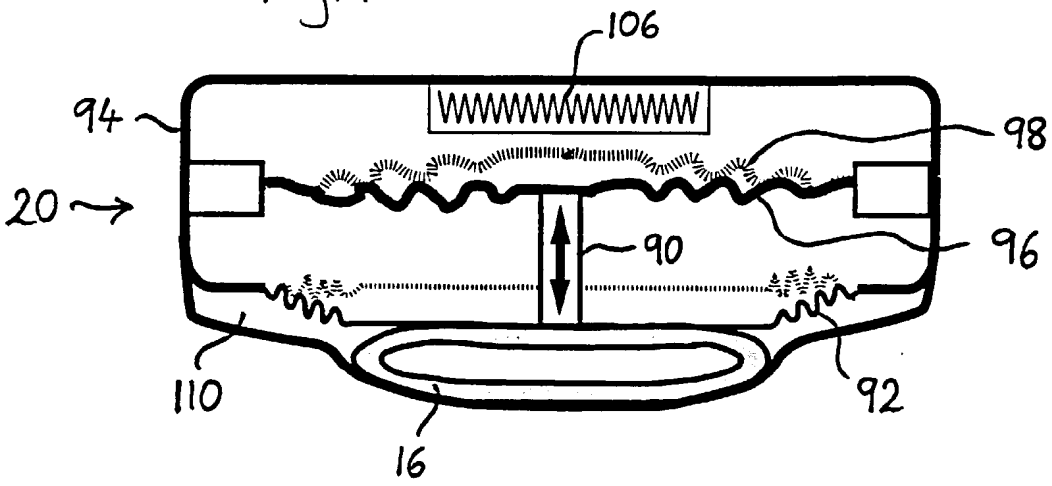


Fig. 8

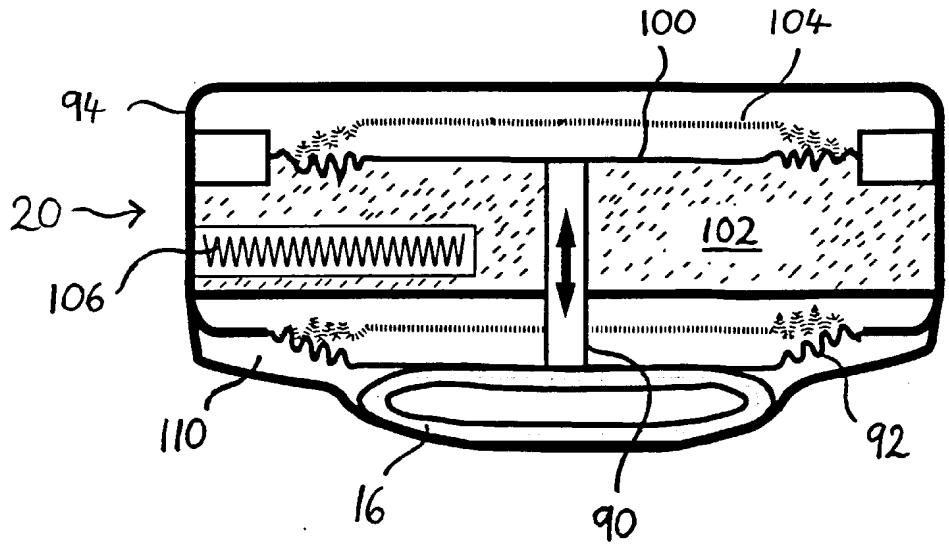


Fig. 9.

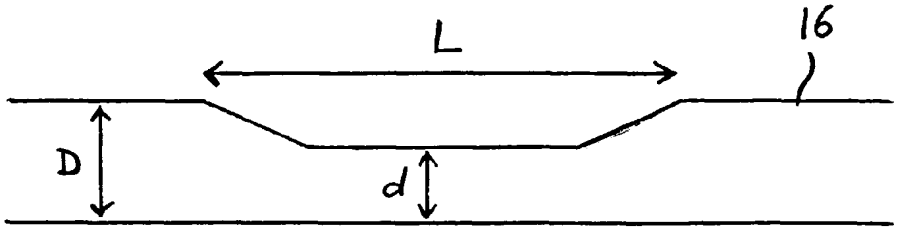


Fig. 10

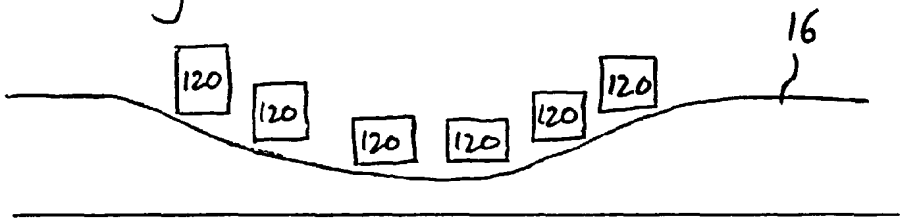
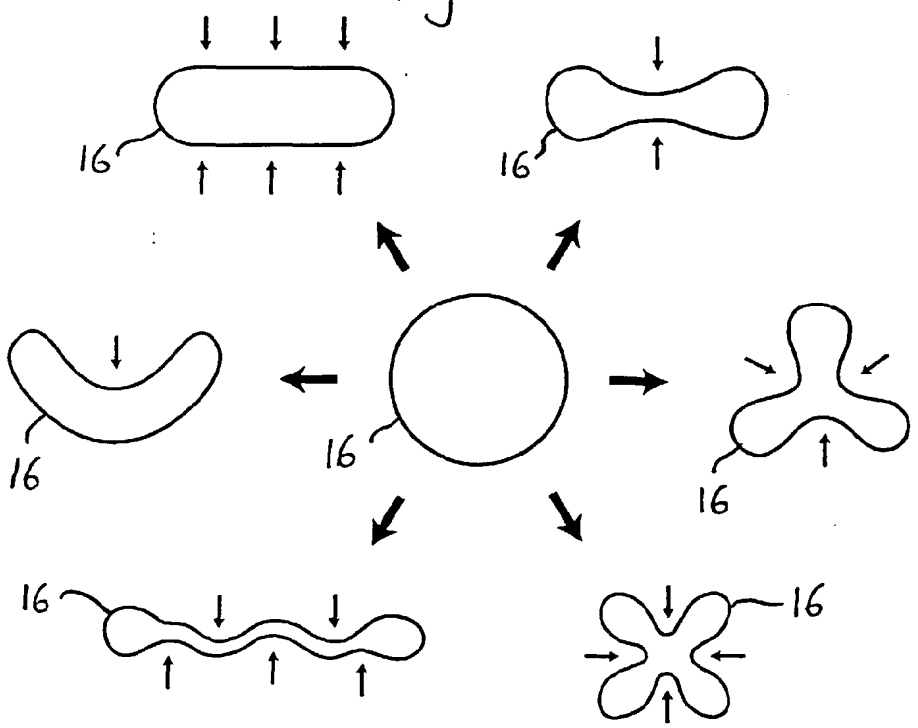


Fig. 11



European Patent Office

PARTIAL EUROPEAN SEARCH REPORT

which under Rule 45 of the European Patent Convention shall be considered, for the purposes of subsequent proceedings, as the European search report

Application Number EP 99 30 5689

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

A61M
A61F
A61B

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC to such an extent that a meaningful search into the state of the art cannot be carried out, or can only be carried out partially, for these claims.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 November 1999	Schönleben, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C07)

European Patent Office

INCOMPLETE SEARCH
SHEET C

Application Number
EP 99 30 5689

Claim(s) not searched:
44-62

Reason for the limitation of the search (non-patentable invention(s)):

Article 52 (4) EPC - Method for treatment of the human or animal body by therapy
Article 52 (4) EPC - Method for treatment of the human or animal body by surgery

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Further limitation of the search

Claim(s) not searched:
63,64

Reason for the limitation of the search:

Rule 29(6) EPC

European Patent Office

PARTIAL EUROPEAN SEARCH REPORT

Application Number
EP 99 30 5689

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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EPO FORM 1503 03.82 (P04C10)

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16-11-1999

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82